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Improved Round Trip Efficiency for Regenerative Fuel Cell Systems

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6. AUTHOR(S)

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13. SUPPLEMENTARY NOTES

14. ABSTRACT

Phase 1 of the project was completed with successful achievement of the go/no go metrics. Additional follow on work is expected for the membrane evaluation but has not yet been exercised. Phase 2 on the regenerative fuel cell system was initiated. Refurbishment of the regenerative fuel cell test stand was initially funded, followed by upgrades to the system later in the quarter. A detailed plan was developed and initiated for oxygen cleaning of the system and reinstallation of parts, and refurbishment is proceeding on schedule. A prototype design for the hydrogen recovery reactor has been developed for procurement of parts and the subcontract for the hermetically sealed compressors has been initiated.

15. SUBJECT TERMS

Regenerative fuel cells, energy density, energy efficiency

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Robert Friedland
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Quarterly Progress Report

Project Title: Improved Round Trip Efficiency for Air Independent Regenerative Fuel Cell Systems

Project Period: June 18, 2010 to December 31, 2011
Date of Report: July 15, 2011

Recipient: Proton Energy Systems
Award Number: N00014-10-C-0369

Working Partners: W. L. Gore, AirSquared
Cost-Sharing Partners: None

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Project Objective:
The purpose of this phase of the effort is advance the understanding, implementation, and operational testing of the features that enable a regenerative fuel cell (RFC) to simultaneously be truly air independent and have high energy density. In addition, follow-on work is expected to investigate advanced membrane materials that enable higher efficiency electrolysis, substantially improving the practical energy density for RFC applications.

Objectives:
- Upgrade RFC system to enable full 4.4 kW fuel cell power output (previous system operated at 2 kW)
- Demonstrate improved closed loop capability through reduction of known mass losses: development of hydrogen recovery reactor and hermetically sealed compressors
- Perform durability testing on the existing RFC breadboard and refine startup and shutdown control systems

Background:
Navy underwater vehicle platforms (UUV, ASDS, SWCS, etc.) are demanding larger and larger energy storage capacities to accommodate longer underwater missions and increased platform power requirements. New energy storage devices with high volumetric energy density for underwater vehicles, both manned and unmanned, are therefore needed, such as regenerative fuel cell (RFC) systems based on proton exchange membrane (PEM) technology. An RFC consists of a fuel cell powerplant, an electrolysis system for recharging the reactants, and reactant storage. These water-

based energy storage systems have been shown to perform substantially better than traditional battery systems in areas such as rechargeability, specific energy density, and reliability. Advanced membrane and catalyst materials will enable higher efficiency electrolysis, substantially improving the practical energy density for regenerative fuel cell applications.

From a full proposal to develop an advanced demonstration system, Task 5 was selected for initial study. This task focused on membrane development and was reported on previously. The next step addressed operation of Proton's regenerative fuel cell system at the full 4.4 kW fuel cell design point and in a truly closed loop mode. The research objectives for Phase 2 of this task were broken into the following separate subtasks:

Task 2: Air-Independent RFC Component Durability Testing
Subtask 2.1: Re-commissioning of the existing RFC system
The contractor shall perform repairs and maintenance to the existing RFC system to achieve operability. Testing at relevant power density shall be initated and baseline mass losses shall be measured.

Subtask 2.2: Upgrade fuel cell output capability
The contractor shall perform design work to determine requirements for doubling the fuel cell output capability. Upgraded components shall be installed and testing shall be performed at higher output power.

Task 3: Dissolved Hydrogen Recovery Reactor
The contractor shall design a hydrogen recovery reactor targeting 2400 psi capability and build a prototype for integration into the RFC system. The contractor shall perform measurement of mass loss at up to 400 psi in order to compare to the baseline measurement.

Task 4: Hermetically Sealed Reactant Circulation Compressors
Improved scroll compressor prototypes shall be specified, procured and tested. The contractor shall integrate the new compressors into the RFC breadboard for testing.

Status:
Phase 2 of the program was kicked off. Refurbishment of the regenerative fuel cell test stand was initially funded, followed by upgrades to the system later in the quarter. A detailed plan was developed and initiated for oxygen cleaning of the system and reinstallation of parts, and refurbishment is proceeding on schedule. A prototype design for the hydrogen recovery reactor has been developed for procurement of parts and the subcontract for the hermetically sealed compressors has been initiated.

Task 2: Air-Independent RFC Component Durability Testing
Subtask 2.1: Re-commissioning of the existing RFC system
Several components of the system were replaced or refurbished based on performance at the last operation of the system and concerns regarding the long storage time.

Specifically, a new replacement fuel cell was ordered and received and the scroll compressor seals were sent out for refurbishment. A detailed plan for oxygen cleaning of parts in the pressurized oxygen loop and reinstallation of parts was initiated and parts were removed and sent out for cleaning.

Subtask 2.2: Upgrade fuel cell output capability
The piping and instrumentation diagram (P&ID) was updated and modified. Leveraging recent work on another program, improvements to the electrochemical/fluids model for this system are under development. Upgraded regulators have been quoted, ordered, and received, and new sections of piping have been fabricated to integrate the high pressure guard bed, improved filters, and upgraded regulators.

Task 3: Dissolved Hydrogen Recovery Reactor
A 2400 psi capable pressure vessel design completed, including mechanical strength analysis. This vessel design will work for both water polishing and as the hydrogen recovery reactor. Parts were ordered and received. Chemical modification of the reactor media is in progress for enhanced activity. Different media and process parameters are being tested, including the surface functional groups of media, reactant concentrations, and reaction time. Physical characterization is in progress to quantify conversion of media after chemical modification. Next steps include activity testing for hydrogen recovery.

Task 4: Hermetically Sealed Reactant Circulation Compressors
The subcontract was finalized with AirSquared, the contractor for development of the hermetically sealed reactant circulation compressors.

Task 1.0 Project Management and Reporting
A kickoff meeting was held internally on March 31, 2011. ONR personnel visited Proton on April 29th. A bimonthly call was held with ONR and Proton personnel on June 22, 2011. Formal test plans have been created and team meetings initiated. Project milestones have been defined.

Plans for Next Quarter and Key Issues:
In the next quarter, work will be completed on the test rig re-assembly. System checkouts will be performed and baseline cycle testing will be initiated. This testing will include testing of the upgraded fuel cell pressure regulation, verifying the electrolyzer water filter, fuel cell heaters and phase separators, and fuel cell compressor seals. Initial characterization of 2 additional media materials for the hydrogen recovery reactor will be completed.

Patents: None to date.

Publications / Presentations:
Slides from the ONR kickoff meeting April 1, 2011 have been released internally. A status update presentation was given to the ONR team on June 22, 2011.

Task Schedule

Task Number	Project Milestones	Task Completion Date				Progress Notes
		Original Planned	Revised Planned	Actual	Percent Complete	
2	Complete test stand refurbishment	8/10/11			70%	
2	Complete baseline testing of recommissioned unit	8/31/11			0%	Not yet started
3	Complete hydrogen recovery reactor testing	10/15/11			25%	Chemical treatment screening in progress
4	Procure hermetically sealed compressors	11/1/11			10%	Subcontract initiated
2	Complete upgrade fabrication/installation	11/30/11			10%	Power components procured
2	Initial multi-day full power testing	12/10/11			0%	Not yet started
1	Project Management				25%	

Budget Summary

Quarter	From	To	Estimated Billing	Actual Billing
2Q11	04/01/11	06/30/11	$217,585	$217,585
3Q11	07/01/11	09/30/11	$363,840	
4Q11	10/01/11	12/31/11	$238,475	
1Q12	01/01/12	03/31/12		
		Totals=	**$819,900**	**$217,585**